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SECTION II: CHAPTER 4

HEAT STRESS

A. INTRODUCTION

Title 8, California Code of Regulations (T8-CCR) does not contain specific requirements to control employee exposure to excessive heat exposures. If a heat stress condition is substantiated, it would be necessary to develop and issue a Special Order to control the harmful exposure.

In addition to the guidelines in this section, there are recommendations published by the American Conference of Governmental Industrial Hygienists (ACGIH) to prevent harmful effects which should be considered in evaluating employee heat exposures. In the Threshold Limit Values (TLVs) for Chemical Substances and Physical Agents, 1995-1996, the ACGIH recommends that workers not be permitted to work when their deep body temperature exceeds 38°C (100.4°F).

Work activities involving high air temperatures, radiant heat sources, high humidity, direct physical contact with hot objects, or strenuous physical activities pose a high potential for inducing heat stress. Heat stress is more likely to occur if employees are required to wear semipermeable or impermeable protective clothing. Hot work activities and work sites that include operations involving the manufacturing, fabrication, remediation and/or construction including:

foundries	brick-firing plants	ceramic plants	rubber factories
glass plants	electrical utilities	attic work	boiler rooms
confectioneries	laundries	bakeries	nonferrous foundries
refineries	commercial kitchens	chemical plants	food canneries
mining sites	smelters	steam tunnels	construction
asbestos removal	gardening	road maintenance	farming
hazardous waste sites			

CAUSAL FACTORS

Age, weight, physical condition, acclimatization, metabolism, use of alcohol or drugs, and a variety of medical conditions such as hypertension can affect a person's sensitivity to heat. Even the type of clothing worn must be considered. Prior heat injury predisposes an individual to additional injury. It is difficult to predict just who will be affected and when, because individual susceptibility varies. Environmental factors leading to potential heat stress are ambient air temperature, radiant heat, air movement, conduction, and relative humidity.

DEFINITIONS

There are certain words and phrases that must be understood to effectively evaluate a heat stress condition. Definitions for the most important words and phrases are as follows:

Heat is a measure of energy in terms of quantity. A calorie is the amount of heat required to raise 1 gram of water 1°C.

Conduction is the transfer of heat between materials that contact each other with heat passing from a warmer material to the cooler material. A worker's skin can transfer heat to a contacting surface if that surface is cooler, and vice versa.

Convection is the transfer of heat in a moving fluid, e.g., cool air flowing past a hot object can cool the object while hot air can warm a cool object. On the other hand, air that exceeds 35°C (95°F) can increase the heat load on the body.

Evaporative cooling, as it relates to human skin, takes place when sweat evaporates. High humidity reduces the rate of evaporation and reduces the effectiveness of the body's primary cooling mechanism.

Thermal radiation is the transfer of heat energy through space whereby an object at a higher temperature than surrounding surfaces radiates heat to objects of a lesser temperature. A worker whose body temperature is greater than the temperature of the surrounding surfaces radiates heat to these surfaces while hot surfaces and infrared light sources radiate heat that can increase the body's heat load.

Metabolic heat is a by-product of the body's activity.

Globe Temperature (GT) is measure of radiant heat using a thermometer inserted inside a blackened, hollow, thin copper globe.

Natural Wet Bulb (NWB) Temperature is a measure of the effects of evaporation and convection using a thermometer equipped with wet sensor, e.g., a wet cotton wick. The term natural refers to the movement of air around the sensor.

Dry Bulb (DB) Temperature is a measure of temperature by a thermal sensor, e.g. an ordinary mercury-in-glass thermometer, shielded from direct radiant energy sources.

Wet Bulb Globe Temperature (WBGT) is a calculated or index temperature related to the effects of heat stress which includes Globe Temperature, Natural Wet Bulb Temperature and, if applicable, Dry Bulb Temperature.

B. HEAT DISORDERS AND HEALTH EFFECTS

Heat disorders can generally be classified into 6 different categories based on their signs and symptoms. Exposure to hot environments can lead to more serious heat related illnesses including Heat Fatigue, Heat Rashes, Heat Collapse ("Fainting"), Heat Cramps, Heat Exhaustion or Heat Stroke.

HEAT FATIGUE

The signs and symptoms of heat fatigue include impaired performance of skilled sensorimotor, mental, or vigilance jobs. A factor that predisposes an individual to heat fatigue is lack of acclimatization to hot environments. The use of a program of acclimatization and training for work in hot environments is advisable. There is no treatment for heat fatigue except to remove the heat stress before a more serious heat-related condition develops.

HEAT RASHES

Heat rashes are the most common problem in hot work environments. Heat rashes normally disappear when the affected individual returns to a cool environment. Heat rash or "prickly heat" is manifested as red inflammatory rash, i.e. papules, usually appearing in areas where clothing is restrictive. As sweating increases, these papules give rise to a prickling sensation. Prickly heat occurs in skin that is persistently wetted by unevaporated sweat, and heat rash papules may become infected if they are not treated.

HEAT COLLAPSE ("Fainting")

In heat collapse, the brain does not receive enough oxygen because blood pools in the extremities which could result in the individual losing consciousness. This reaction is similar to that of heat exhaustion and does not affect the body's heat balance but the onset of heat collapse is rapid and unpredictable. To prevent heat collapse, the worker should gradually become acclimatized to the hot environment.

HEAT CRAMPS

Heat cramps are usually associated with performing hard physical labor in a hot environment. Heat cramps appear to be caused by a lack of water replenishment leading to an electrolyte imbalance caused by sweating. Cramps can be caused by both too much and too little salt. Since sweat is a hypotonic solution ($\pm 0.3\%$ NaCl), excess salt can build up in the body if the water lost through sweating is not replaced. Thirst cannot be relied on as a guide to the need for water; instead, water must be taken every 15 to 20 minutes in hot environments. Under extreme conditions, such as working for 6 to 8 hours in heavy protective gear, a loss of sodium may occur.

Studies have shown that drinking commercially available carbohydrate- electrolyte replacement liquids is effective in minimizing physiological disturbances during recovery.

HEAT EXHAUSTION

The signs and symptoms of heat exhaustion are headache, nausea, vertigo, weakness, thirst, and giddiness. The signs and symptoms are similar to those of heat stroke and should be considered to constitute a medical emergency. Individuals experiencing heat exhaustion usually readily respond to prompt treatment. Heat exhaustion can lead to fainting and may result in a fall injury. This can be extremely dangerous if the victim is operating machinery or controlling an operation that should not be left unattended. Heat exhaustion should not be dismissed lightly because of the potential serious consequences of quickly developing into a heat stroke condition. Workers suffering from heat exhaustion should be removed from the hot environment, given fluid replacement and get adequate rest.

HEAT STROKE

Heat stroke is a medical emergency. The primary signs and symptoms of heat stroke are confusion, irrational behavior; loss of consciousness, convulsions, lack of sweating (usually); hot, dry skin, and an abnormally high body temperature, e.g., a rectal temperature of 41°C (105.8°F). If body temperature is too high, it causes death. Heat stroke occurs when the body's system of temperature regulation fails and body temperature rises to critical levels. This condition is caused by a combination of highly variable factors, and its occurrence is difficult to predict. The elevated metabolic temperatures caused by a combination of work load and environmental heat load, both of which contribute to heat stroke, are also highly variable and difficult to predict.

If a worker shows signs of possible heat stroke, professional medical treatment must be obtained immediately. The worker should be placed in a shady area and the outer clothing removed. The worker's skin should be wetted and air movement around the worker increased to improve evaporative cooling until professional methods of cooling are initiated and the seriousness of the condition can be assessed. Fluids should be replaced as soon as possible. The medical outcome of heat stroke depends on the victim's physical condition and the timing and effectiveness of first aid treatment. Regardless of the worker's protests, no employee suspected of being ill from heat stroke should be sent home or left unattended unless a physician has specifically approved such an order.

C. INVESTIGATION GUIDELINES

Guidelines for evaluating employee heat stress contained in this section approximate those found in the 1995-1996 ACGIH's, Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. The ACGIH's publication should be consulted for additional information.

Appendix II:4-1A lists factors to be evaluated when reviewing a heat stress situation, and Appendix II:4-1B contains a follow-up checklist.

INSPECTION PROCEDURE

When conducting a heat stress related inspection, compliance personnel shall:

- * Review OSHA 200 log, 5020 and 5021 forms to identify prior heat stress problems,
- * Evaluate the action taken to prevent heat stress exposures,
- * Identify potential sources of heat stress,
- * Determine if employees have made heat stress complaints,
- * Determine if employees have experienced heat stress problems,
- * Evaluate actions taken to minimize heat stress,
- * Review heat stress training program,
- * Perform wbgt measurements,
- * Document the type of work activity performed,
- * Document what engineering and/or administrative controls are in place,
- * Verify the existing engineering controls are functioning properly,
- * Determine if additional engineering and/or administrative controls are feasible,
- * Evaluate the type of personal protective equipment being used,
- * Solicit employer and employee suggestions for controlling heat exposures,
- * Determine if addition or different personal protective equipment is needed,
- * Evaluate the medical surveillance and first aid program,
- * Determine building and operation characteristics,
- * Verify information obtained from the employer and employee interviews.

The inspection should cover all affected areas and heat sources, e.g., furnaces, ovens, and boilers and include documentation on the heat load per employee. It may be necessary to discuss the inspection finding with the Senior Industrial Hygienist, Medical Unit and other knowledgeable personnel to determine if the conditions constitute a heat stress hazard and/or feasibility of engineering controls.

HEAT STRESS EVALUATION

Work Activity

Work activities which must be considered in a heat stress evaluation are outlined in Figure II:4-1. These work activities, along with WBGT measurement and metabolic rates associated with specific activities are used in the assessment of an individual's heat stress.

To evaluate the potential for heat stress, the type of work activity or combination of work activities must be classified using Figure II:4-1.

FIGURE II:4-1. ACTIVITY EXAMPLES

*	Light hand work: writing, hand knitting
*	Heavy hand work: typewriting
*	Heavy work with one arm: hammering in nails (shoemaker, upholsterer)
*	Light work with two arms: filing metal, planing wood, raking the garden
*	Moderate work with the body: cleaning a floor, beating a carpet
*	Heavy work with the body: railroad track laying, digging, barking trees

Metabolic Rate

The ACGIH has suggested various values related to the metabolic rate of an individual while performing various work activities. Metabolic rates are based on (1) body position and movement and (2) the type of physical work being performed as part of the assessment of an employee's workload.

A calculation can be made to determine the overall estimated average metabolic rate of an individual based on the type of work being performed and the body position and movement related to that work. A sample calculation is illustrated in FIGURE II:4-2.

TABLE II:4-1. ASSESSMENT OF WORK LOAD

PART I - BODY POSITION AND MOVEMENT		
DESCRIPTION	KCAL/MIN*	
Sitting	0.3	
Standing	0.6	
Walking	2.0-3.0	
Walking uphill	add 0.8 for every meter (yard) rise	
PART II - TYPE OF WORK		
TYPE OF WORK	AVERAGE KCAL/MIN	RANGE KCAL/MIN
Hand work		
Light	0.4	0.2-1.2
Heavy	0.9	
Work: One arm		
Light	1.0	0.7-2.5
Heavy	1.7	
Work: Both arms		
Light	1.5	1.0-3.5
Heavy	2.5	
Work: Whole body		
Light	3.5	2.5-15.0
Moderate	5.0	
Heavy	7.0	
Very heavy	9.0	
* For a "standard" worker of 70 kg body weight (154 lbs) and 1.8 m ² body surface (19.4 ft ²).		

Source: ACGIH 1995-1996.

FIGURE II:4-2.
SAMPLE CALCULATION OF ESTIMATED AVERAGE METABOLIC RATE

Given : Assembly line work involving walking, light body work and both arms using a heavy hand tool.	
TYPE OF WORK/BODY POSITION	AVERAGE METABOLIC RATE (KILOCALORIES/ MINUTE)
Walking along	2.0 kcal/min
Intermediate value between heavy work with two arms and light work with the body	3.0 kcal/min
Basal metabolism	1.0 kcal/min
<hr/>	
Total metabolic rate for employee	6.0 kcal/min

Source: ACGIH 1995-1996

WORK-LOAD ASSESSMENT

Under conditions of high temperature and heavy workload, it will be necessary to determine the work-load category of each job (Table II:4-1 and Figure II:4-2). Work-load is determined by averaging metabolic rates for the tasks and then ranking the work into one of the categories listed in Figure II:4-3.

FIGURE II:4-3

WORK LOAD CATEGORIES	
*	Light work: up to 200 kcal/hour
*	Medium work: 200 to 350 kcal/hour
*	Heavy work: 350 to 500 kcal/hour

Consideration must be given to work activities that include no physical work in a Cool Rest Area. Where heat conditions in the rest area are different from those in the work area, the metabolic rate (M) should be calculated using a time-weighted average formula shown in FIGURE II:4-4. In some cases, a video tape is helpful in evaluating work practices and metabolic load.

FIGURE II:4-4
TIME-WEIGHTED AVERAGE METABOLIC RATE

$$\text{Average M} = \frac{M_1 * t_1 + M_2 * t_2 \dots + M_n * t_n}{t_1 + t_2 \dots + t_n}$$

where: M = metabolic rate
t = time in minutes.

D. SAMPLING METHODS

BODY TEMPERATURE MEASUREMENTS

Although instruments are available to estimate deep body temperature by measuring the temperature in the ear canal or on the skin, these instruments are not sufficiently reliable to use in compliance evaluations.

ENVIRONMENTAL MEASUREMENTS

Environmental heat measurements should be made at, or as close as possible to, the exposed employee work position. When an employee is not continuously exposed in a single hot area but moves between two or more areas having different levels of environmental heat, or when the environmental heat varies substantially at a single hot area, environmental heat exposures must be measured for each area and for each level of environmental heat to which employees are exposed.

WET BULB GLOBE TEMPERATURE INDEX

The Wet Bulb Globe Temperature (WBGT) Index is the method that will be used to assess heat stress. The WBGT will be calculated using the appropriate formula as shown in Appendix II:4-2. The WBGT for continuous all-day or several hour exposures should be averaged over a 60-minute period.

Intermittent exposures should be averaged over a 120-minute period. These averages should be calculated using the following formula shown in Figure II:4-5:

**FIGURE II:4-5
CALCULATION OF AVERAGE WBGT**

$$\text{Average WBGT} = \frac{\text{WBGT}_1 * t_1 + \text{WBGT}_2 * t_2 \dots + \text{WBGT}_n * t_n}{t_1 + t_2 \dots + t_n}$$

where:

WBGT = Wet Bulb Globe Temperature Index
NWB = Nature Wet-Bulb Temperature
DB = Dry-Bulb Temperature
GT = Globe Temperature

For indoor and outdoor conditions with no solar load, WBGT is calculated as by the formula shown in Figure II:4-6-A and for outdoor with a solar load, calculated using the formula in Figure II:4-6-B.

FIGURE II:4-6-A
CALCULATION OF WBGT WITH NO SOLAR LOAD

$$\text{WBGT} = 0.7 \text{ NWB} + 0.3 \text{ GT}$$

FIGURE II:4-6-B
CALCULATION OF WBGT WITH A SOLAR LOAD

$$\text{WBGT} = 0.7 \text{ NWB} + 0.2 \text{ GT} + 0.1 \text{ DB}$$

where:

WBGT	=	Wet Bulb Globe Temperature Index
NWB	=	Nature Wet-Bulb Temperature
DB	=	Dry-Bulb Temperature
GT	=	Globe Temperature

The exposure limits in Table II:4-2 are valid for employees wearing light clothing. The exposure limits must be adjusted for the insulation from clothing that impedes sweat evaporation and other body cooling mechanisms. Use Table II:4-3 to correct Table II:4-2 for various kinds of clothing.

Use of Table II:4-2 requires knowledge of the WBGT and approximate workload. Workload can be estimated using the data in Table II:4-1, and sample calculations are presented in Figure II:4-1.

MEASUREMENT

Portable heat stress monitoring devices are used to measure heat conditions. These instruments can calculate both the indoor and outdoor WBGT index according to established ACGIH Threshold Limit Value equations. With this information and information on the type of work being performed, heat stress meters can determine how long a person can safely work or remain in a particular hot environment.

Appendix II:4-2 provide for an alternate method of calculating the WBGT Index.

The ACGIH recommended permissible heat exposure threshold limit values (TLVs) for heat stress are shown in TABLE II:4-2. The table lists the work and rest regime and the TLV

temperature, in °C and °F which should not be exceeded.

**TABLE II:4-2.
PERMISSIBLE HEAT EXPOSURE THRESHOLD LIMIT VALUES**

----- WORK LOAD* -----			
Work/rest regimen	Light	Moderate	Heavy
Continuous work	30.0°C (86°F)	26.7°C (80°F)	25.0°C (77°F)
75% Work, 25% rest, each hour	30.6°C (87°F)	28.0°C (82°F)	25.9°C (78°F)
50% Work, 50% rest, each hour	31.4°C (89°F)	29.4°C (85°F)	27.9°C (82°F)
25% Work, 75% rest, each hour	32.3°C (90°F)	31.1°C (88°F)	30.0°C (86°F)
* Values are in °C and °F, WBGT.			

Source: ACGIH 1996-1996

The ACGIH TLV recommendations are based on the assumption that nearly all acclimatized, fully clothed workers with adequate water and salt intake should be able to function effectively under the given working conditions without exceeding a deep body temperature of 38°C (100.4°F). They are also based on the assumption that the WBGT of the work area is different from that of the rest area, a time-weighted average should be used (consult the ACGIH 1995-1996 or most recent edition of the Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices).

The TLVs apply to physically fit and acclimatized individuals wearing light summer clothing. If heavier clothing that impede sweat or has a higher insulation value is required, the permissible heat exposure TLVs in Table II:4-2 must be reduced by the corrections shown in Table II:4-3.

OTHER THERMAL STRESS INDICES

The effective temperature index (ET) combines the temperature, the humidity of the air, and air velocity. This index has been used extensively in the field of comfort ventilation and air-conditioning. ET remains a useful measurement technique in mines and other places where humidity is high and radiant heat is low.

The Heat-Stress Index (HSI) was developed by Belding and Hatch in 1965. Although the HSI considers all environmental factors and work rate, it is not completely satisfactory for determining an individual worker's heat stress and is also difficult to use.

TABLE II:4-3.
WBGT CORRECTION FACTORS IN DEGREES C FOR CLOTHING

CLO* CLOTHING TYPE	VALUE	WBGT CORRECTION
Summer lightweight working clothing	0.6	0
Cotton coveralls	1.0	-2
Winter work clothing	1.4	-4
Water barrier, permeable (Gortex)	1.2	-6
Vapor barrier (Tyvek)	1.2	-10
*CLO: Insulation value of clothing. One CLO = 5.55 kcal/m ² /hr of heat exchange by radiation and convection for each degree C difference in temperature between the skin and the adjusted dry bulb temperature.		

Source: ACGIH 1995-1996.

E. CONTROL

Ventilation, air cooling, fans, shielding, and insulation are the five major types of engineering controls used to reduce heat stress in hot work environments. Proper selection of clothing and personal cooling devices , e.g., vortex coolers and cool vests, may assist in reducing the heat stress potential. Heat reduction can also be achieved by using power assists and tools that reduce the physical demands placed on a worker. However, for this approach to be successful, the metabolic effort required for the worker to use or operate these devices must be less than the effort required without them. Another method is to reduce the effort necessary to operate power assists. The worker should be allowed to take frequent rest breaks in a cooler environment.

ACCLIMATIZATION

The human body can adapt to heat exposure to some extent. This physiological adaptation is called acclimatization. After a period of acclimatization, the same activity will produce fewer cardiovascular demands. The worker will sweat more efficiently causing better evaporative cooling, and will more easily be able to maintain normal body temperatures. A properly designed and applied acclimatization program decreases the risk of heat-related illnesses. Such a program basically involves exposing employees to work in a hot environment for progressively longer periods.

NIOSH (1986) states that, for workers who have had previous experience in jobs where heat levels are high enough to produce heat stress, the regimen should be 50% exposure on day 1, 60% on day 2, 80% on day 3, and 100% on day 4. For new workers who will be similarly exposed, the regimen should be 20% on day 1, with a 20% increase in exposure each additional day.

FLUID REPLACEMENT

Cool (50-60°F) water or any cool liquid, except alcoholic beverages, should be made available to workers to encourage them to drink small amounts frequently, e.g., one cup every 20 minutes. Ample supplies of liquids should be placed close to the work area. Although some commercial replacement drinks contain salt, this is not necessary for acclimatized individuals because most people add enough salt to their summer diets.

ENGINEERING CONTROLS

General ventilation is used to dilute hot air usually with cooler air that is brought in from the outside. This technique clearly works better in cooler climates than in hot ones. A permanently installed ventilation system usually handles large areas or entire buildings. Portable or local exhaust systems may be more effective or practical in smaller areas.

Air treatment/air cooling differs from ventilation because it reduces the temperature of the air by removing heat, and sometimes humidity, from the air. Air conditioning is a method of air cooling, but it is expensive to install and operate. An alternative to air conditioning is the use of chillers to circulate cool water through heat exchangers over which air from the ventilation system is then passed; chillers are more efficient in cooler climates or in dry climates where evaporative cooling can be used. Local air cooling can be effective in reducing air temperature in specific areas. Two methods have been used successfully in industrial settings. One type, cool rooms, can be used to enclose a specific workplace or to offer a recovery area near hot jobs. The second type is a portable blower with built-in air chiller. The main advantage of a blower, aside from portability, is minimal set-up time.

Convection

Another way to reduce heat stress is to increase the air flow or convection using fans in the work area. This method is beneficial as long as the air temperature is less than the worker's skin temperature. Changes in air speed can help employees stay cooler by increasing both the convective heat exchange, i.e., the exchange between the skin surface and the surrounding air, and the rate of evaporation. Because this method does not actually cool the air, any increases in air speed must impact the employee directly to be effective.

If the dry bulb temperature is higher than 35°C (95°F), the hot air passing over the skin can actually make the employee hotter. When the temperature is more than 35°C and the air is dry, evaporative cooling may be improved by air movement, although this improvement will be offset by the convective heat. When the temperature exceeds 35°C and the relative humidity is 100%, air movement will make the employee hotter. Increases in air speed have no effect on the body temperature of the worker wearing vapor-barrier clothing.

Heat Conduction

Heat conduction methods include insulating the hot surface that generates the heat and changing the surface itself.

Radiant Heat

Installation of engineering controls, such as shields, can be used to reduce radiant heat, i.e, heat coming from hot surfaces within the worker's line of sight. Surfaces that exceed 35°C (95°F) are sources of infrared radiation that can add to the worker's heat load. Flat black surfaces absorb heat more than smooth, polished ones. Having cooler surfaces surrounding the worker assists in cooling because the worker's body radiates heat toward them.

With some sources of radiation, such as heating pipes, it is possible to use both insulation and surface modifications to achieve a substantial reduction in radiant heat. Instead of reducing radiation from the source, shielding can be used to interrupt the path between the source and the worker. Polished surfaces make the best barriers, although special glass or metal mesh surfaces can be used if visibility is a problem. Shields should be located so that they do not interfere with

air flow, unless they are also being used to reduce convective heating. The reflective surface of the shield should be kept clean to maintain its effectiveness.

ADMINISTRATIVE CONTROLS AND WORK PRACTICES

Training is the key to good work practices. Unless all employees understand the reasons for using new, or changing old, work practices, the chances of such a program succeeding are greatly reduced.

NIOSH (1986) states that a good heat stress training program should include at least the following components:

- * Knowledge of the hazards of heat stress,
- * Recognition of predisposing factors, danger signs, and symptoms,
- * Awareness of first-aid procedures for, and the potential health effects of, heat stroke,
- * Employee responsibilities in avoiding heat stress,
- * Dangers of using drugs, including therapeutic ones, and alcohol in hot work environments,
- * Use of protective clothing and equipment, and
- * Purpose and coverage of environmental and medical surveillance programs and the advantages of worker participation in such programs.

Hot jobs should be scheduled for the cooler part of the day, and routine maintenance and repair work in hot areas should be scheduled for the cooler seasons of the year.

WORKER MONITORING PROGRAMS

Every worker who works in extraordinary conditions that increase the risk of heat stress should be personally monitored. These conditions include wearing semipermeable or impermeable clothing when the temperature exceeds 21°C (69.8°F), working at extreme metabolic loads, e.g., greater than 500 kcal/hour.

Personal monitoring can be done by checking the heart rate, recovery heart rate, oral temperature, or extent of body water loss. To check the heart rate, count the radial pulse for 30 seconds at the beginning of the rest period. If the heart rate exceeds 110 beats per minute, shorten the next work period by one third and maintain the same rest period. The recovery heart rate can be checked by comparing the pulse rate taken at 30 seconds (P_1) with the pulse rate taken at 2.5 minutes (P_3) after. The two pulse rates can be interpreted using Table II:4-4.

Oral temperature can be checked with a clinical thermometer after work but before the employee drinks water. If the oral temperature taken under the tongue exceeds 37.6°C, shorten the next work cycle by one third.

Body water loss can be measured by weighing the worker on a scale at the beginning and end of

each work day. The worker's weight loss should not exceed 1.5% of total body weight in a work day. If a weight loss exceeding this amount is observed, fluid intake should increase.

OTHER ADMINISTRATIVE CONTROLS

The following administrative controls can be used to reduce heat stress:

- * Reduce the physical demands of work, e.g., excessive lifting or digging with heavy objects.
- * Provide recovery areas, e.g., air-conditioned enclosures and rooms.
- * Use shifts, e.g., early morning, cool part of the day, or night work.
- * Use intermittent rest periods with water breaks.
- * Use relief workers.
- * Use worker pacing.
- * Assign extra workers and limit worker occupancy, or the number of workers present, especially in confined or enclosed spaces.

**TABLE II:4-4.
HEART RATE RECOVERY CRITERIA**

HEART RATE RECOVERY PATTERN	DIFFERENCES BETWEEN	
	P_3	P_1 AND P_3
Satisfactory Recovery	< 90	---
High Recovery (Conditions require further study) 90		10
No Recovery (May indicate too much stress)	90	< 10

F. PERSONAL PROTECTIVE EQUIPMENT

REFLECTIVE CLOTHING

Reflective clothing, which can vary from aprons and jackets to suits that completely enclose the worker from neck to feet, can stop the skin from absorbing radiant heat. However, since most reflective clothing doesn't allow air exchange through the garment, the reduction of radiant heat must more than offset the corresponding loss in evaporative cooling. For this reason, reflective clothing should be worn as loosely as possible. In situations where radiant heat is high, auxiliary cooling systems can be used under the reflective clothing.

AUXILIARY BODY COOLING

Commercially available cool water and ice vests, though heavy, may assist in cooling the body. Ice vests may accommodate as many as 72 ice packets, which are usually filled with water. The cooling offered by ice packets lasts only 2 to 4 hours at moderate to heavy heat loads, and frequent replacement is necessary. However, ice vests do not encumber the worker and thus permit maximum mobility. Cooling with ice is also relatively inexpensive. Carbon dioxide (dry ice) can also be used as a coolant.

Wetted clothing is another simple and inexpensive personal cooling technique. It is effective when reflective or other impermeable protective clothing is worn. The clothing may be wetted terry cloth coveralls or wetted two-piece, whole-body cotton suits. This approach to auxiliary cooling can be quite effective under conditions of high temperature and low humidity, where evaporation from the wetted garment is not restricted. Water-cooled garments range from a hood, which cools only the head, to vests and "long-johns," which offer partial or complete body cooling. Use of this equipment requires a battery-driven circulating pump, liquid-ice coolant, and a container.

Although this system has the advantage of allowing wearer mobility, the weight of the components limits the amount of ice that can be carried and thus reduces the effective use time. The heat transfer rate in liquid cooling systems may limit their use to low-activity jobs; even in such jobs, their service time is only about 20 minutes per pound of cooling ice. To keep outside heat from melting the ice, an outer insulating jacket should be an integral part of these systems.

Circulating air is the most highly effective, as well as the most complicated, personal cooling system. By directing compressed air around the body from a supplied air system, both evaporative and convective cooling are improved. The greatest advantage occurs when circulating air is used with impermeable garments or double cotton overalls. One type, used when respiratory protection is also necessary, forces exhaust air from a supplied-air hood ("bubble hood") around the neck and down inside an impermeable suit. The air then escapes through openings in the suit.

Air can also be supplied directly to the suit without using a hood. This can be done in three ways:

- * by a single inlet,
- * by a distribution tree, or
- * by a perforated vest.

In addition, a vortex tube can be used to reduce the temperature of circulating air. The cooled air from this tube can be introduced either under the clothing or into a bubble hood. The use of a vortex tube separates the air stream into a hot and cold stream; these tubes also can be used to supply heat in cold climates. Circulating air, however, is noisy and requires a constant source of compressed air supplied through an attached air hose. One problem with this system is the limited mobility of workers whose suits are attached to an air hose. Another is that of getting air to the work area itself. These systems should therefore be used in work areas where workers are not required to move around much or to climb. Another concern with these systems is that they can lead to dehydration. The cool, dry air feels comfortable and the worker may not realize that it is important to drink liquids frequently.

Respirator Usage

The weight of a self-contained breathing apparatus (SCBA) increases stress on a worker, and this stress contributes to overall heat stress. Chemical protective clothing such as totally encapsulating chemical protection suits will add significantly to the heat stress problem.

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APPENDIX II:4-1A. HEAT STRESS: GENERAL WORK-PLACE REVIEW

Note: Listed below are sample questions that the Compliance Personnel may wish to consider asking when investigating heat stress in the workplace.

WORK-PLACE DESCRIPTION

- A. Type of business
- B. Heat-producing equipment or processes used
- C. Previous history (if any) of heat-related problems
- D. At "hot" spots:
 - 1. Is the heat steady or intermittent?
 - 2. Number of employees exposed?
 - 3. For how many hours per day?
 - 4. Is potable water available?
 - 5. Are supervisors trained to detect/evaluate heat stress symptoms?

ARE EXPOSURES TYPICAL FOR A WORK-PLACE IN THIS INDUSTRY?

Weather at Time of Review

- A. Temperature
- B. Humidity
- C. Air velocity

Is Day Typical of Recent Weather Conditions?

Such information may be obtained from the Weather Bureau or Air Quality Management District.

Heat-Reducing Engineering Controls

- A. Ventilation in place?
- B. Ventilation operating?
- C. Air conditioning in place?
- D. Air conditioning operating?
- E. Fans in place?
- F. Fans operating?
- G. Shields or insulation between sources and employees?
- H. Are reflective faces of shields clean?

WORK PRACTICES TO DETECT, EVALUATE, AND PREVENT OR REDUCE HEAT STRESS

- A. Training program?
 - 1. Content?
 - 2. Where given?
 - 3. For whom?
- B. Liquid replacement program?
- C. Acclimatization program?
- D. Work/rest schedule?
- E. Scheduling of work during cooler parts of shift, cleaning and maintenance during shut-downs, etc.
- F. Cool rest areas (including shelter at outdoor work sites)?
- G. Heat monitoring program?

Personal Protective Equipment

- A. Reflective clothing in use?
- B. Ice and/or water-cooled garments in use?
- C. Wetted undergarments used with reflective or impermeable clothing in use?
- D. Circulating air systems in use?

First Aid Program

- A. Trained personnel?
- B. Provision for rapid cool-down?
- C. Procedures for getting medical attention?
- D. Transportation to medical facilities readily available for heat stroke victims?

Medical Screening and Surveillance Program

- A. Content?
- B. Who manages program?

Additional Comments

Use additional pages as needed.

APPENDIX II:4-1B. HEAT STRESS-RELATED ILLNESS OR ACCIDENT FOLLOW-UP

- A. Describe events leading up to the episode.
- B. Evaluation/comments by other workers at the scene.
 - 1. Work at time of episode (heavy, medium, light)?
 - 2. How long was affected employee working at site prior to episode?
 - 3. Medical history of affected worker, if known.
- C. Appropriate engineering controls in place?
- D. Appropriate engineering controls in operation?
- E. Appropriate work practices used by affected employee(s)?
- F. Appropriate personal protective equipment available?
- G. Appropriate personal protective equipment in use?
- H. Medical screening for heat stress and continued surveillance for signs of heat stress given other employees?
- I. Additional comments regarding specific episode(s): (Use additional pages as needed.)

APPENDIX II:4-2. MEASUREMENT OF WET BULB GLOBE TEMPERATURE

Measurement is often required of those environmental factors that most nearly correlate with deep body temperature and other physiological responses to heat. At the present time, the Wet Bulb Globe Temperature Index (WBGT) is the most used technique to measure these environmental factors. WBGT values are calculated by the following equations:

1. Indoors or outdoors with no solar load: $WBGT = 0.7 NWB + 0.3GT$
2. Outdoors with solar load: $WBGT = 0.7 NWB + 0.2GT + 0.1 DB$
where: WBGT = Wet Bulb Globe Temperature Index
NWB = Natural Wet-Bulb Temperature
DB = Dry-Bulb (air) Temperature
GT = Globe Thermometer Temperature.

The determination of WBGT requires the use of a black globe thermometer, a natural (static) wet-bulb thermometer, and a dry-bulb thermometer. The measurement of environmental factors shall be performed as follows:

1. The range of the dry and the natural wet-bulb thermometers should be -5°C to $+50^{\circ}\text{C}$, with an accuracy of $\pm 0.5^{\circ}\text{C}$. The dry bulb thermometer must be shielded from the sun and the other radiant surfaces of the environment without restricting the airflow around the bulb. The wick of the natural wet bulb thermometer should be kept wet with distilled water for at least $\frac{1}{2}$ hour before the temperature reading is made. It is not enough to immerse the other end of the wick into a reservoir of distilled water and wait until the whole wick becomes wet by capillarity. The wick must be wetted by direct application of water from a syringe $\frac{1}{2}$ hour before each reading. The wick must cover the bulb of the thermometer and an equal length of additional wick must cover the stem above the bulb. The wick should always be clean, and new wicks should be washed before using.
2. A globe thermometer, consisting of a 15 cm (6-inch) in diameter hollow copper sphere painted on the outside with a matte black finish, or equivalent, must be used. The bulb or sensor of a thermometer (range -5°C to $+100^{\circ}\text{C}$ with an accuracy of $\pm 0.5^{\circ}\text{C}$) must be fixed in the center of the sphere. The globe thermometer should be exposed at least 25 minutes before it is read.
3. A stand should be used to suspend the three thermometers so that they do not restrict free air flow around the bulbs and the wet-bulb and globe thermometer are not shaded.
4. It is permissible to use any other type of temperature sensor that gives a reading similar to that of a mercury thermometer under the same conditions.
5. The thermometers must be placed so that the readings are representative of the employee's work or rest areas, as appropriate.

Once the WBGT has been estimated, employers can estimate workers' metabolic heat load (see Tables II:4-1 and II:4-2) and use the ACGIH method to determine the appropriate work/rest regimen, clothing, and equipment to use to control the heat exposures of workers in their facilities.